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Research into Dry Turning of Welded Surface by Replaceable Cutting Insert with Closed Loop Heat Removal

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Abstract. A special tool has been devised incorporating a closed loop system based on Peltier thermoelectric couples to cool replaceable hard alloy inserts. Experimental research has been done into dry turning of a X20Cr13 steel welded surface with a SECO cubic boron nitride circular plate at the cutting speed increasing from 100 to 300 m/min. It has been determined that Ra surface roughness decreases by 22% while Rz surface roughness goes down by 26%; in addition, the wear flat of tool tips diminishes by 17%.

1. Introduction

Turning is accompanied by intensive heat generation due to friction interaction and deformation of the material that is being removed; it is made obvious by high temperatures of the chip, the cutter and the work-piece [1-5]. Growing temperature of the machined material produces an adverse effect on the quality of machining; heating of the cutter brings about lower hardness of the tool tip, its quick dulling, which significantly reduces tool durability [2]. The intensity of heat generation is influenced by the properties of the machined material, that of the tool, the geometry of the cutter, and cutting modes. The biggest impact is made by cutting speeds while the feed and the cutting depth produce a lesser influence [3].

The heat generated in turning is distributed between the chip, the cutter and the work-piece. The biggest share of heat goes into the chip; the rest of it is distributed between the cutter and the work-piece. According to [4-5] the amount of heat diverted into the tool falls from ~60 to 18% when cutting speeds applied to AISI 316L and AISI 1045 steels are increased from 10 to 80 m/min. As the speed is further increased, the correlation of thermal flows does not change. As far as the quality of machining, tool life and production rate are concerned, most favorable conditions occur at a cutting speed of 50 m/min when the intensity of heat generation is relatively low and the heat transfer into the tool amounts to ~30%. Optimal cutting speeds recommended by SECO in regard to machining chromium steels with PCBN inserts range within 50...100 m/min.

In order to provide for high-quality machining and long tool life at higher cutting speeds it is necessary that the fraction of heat relieved from the cutting zone into the tool should be increased if the cutting speeds are to be increased. As soon as external application of a lubricant for dry cutting is impossible and cooling of the work-piece is not efficient, the only remaining approach offering prospects for the future is to internally remove heat from the replaceable cutting insert.

A number of approaches toward producing turning tools with internal cooling of replaceable turning plates (RTP) are described in the papers [6-8]. The operational principle of these systems is aimed at supplying a cooling liquid to the base of the RTP through channels provided inside the tool holder.



The paper [6] reports on an open loop system through which a liquid heat medium is pumped. The system seems easy to fabricate: at the same time, it is in need of an efficient pumping unit, its application is associated with high consumption of cooling liquid. The papers [7, 8] present a two-stage system with a closed loop, its operation based on evaporation of a liquid coolant under a replaceable turning plate. The closed loop system features more efficient cooling of the RTP; somehow, due to the large dimensions of its condenser its application for mass production seems difficult.

A more efficient cooling system is presented in the papers [9-10]; it is designed to increase production rates of nanostructuring burnishing. An open loop system [9] employing high-pressure pumping of a coolant in the interior of the tool provides for a possibility to increase the rate of machining of X20Cr13 (43...45 HRC) steel by 65%. The closed loop cooling system built on Peltier thermoelectric couples has proven to be very efficient in removing heat from the tool, making it possible to raise the rate of burnishing by 2.2 [11].

The purpose of the present research is to determine the impact of internal heat removal, relieving heat from RTP's of the PCBN type, on the smoothness of machined surfaces and tool life in the case of dry turning of welded material at a cutting speed 3 times higher than the recommended value.

2. Experimental setup

To do the experimental study a turning tool was devised equipped with an internal closed loop for cooling its RTP (Fig. 1). High intensity of its heat removal is achieved by decreasing the temperature of the coolant in the closed loop which comprises a heat exchanger with four integrated Peltier thermoelectric couples. The cooling performance of the Peltier thermoelectric unit is 400 W; it enabled to maintain the temperature of the coolant at 9 °C when the turning speed was increased to 300 m/min.

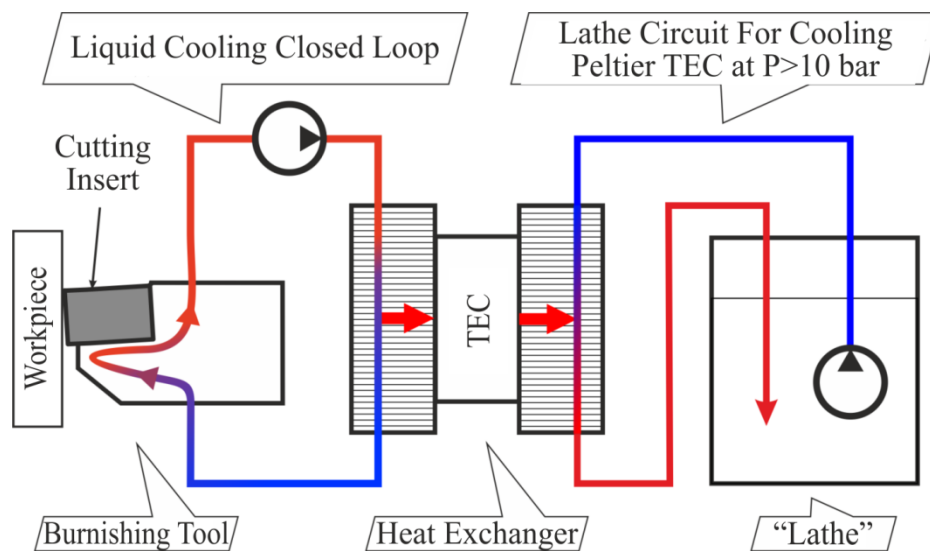


Figure 1. Liquid cooling closed loop system for cooling the replaceable insert based on Peltier thermoelectric couple

A disk-shaped sample used in the experiment was made from X20Cr13 steel (as delivered); a X20Cr13 steel layer 5 mm thick was welded to it, its hardness measuring from 45 to 48 HRC. Turning was done on an Okuma Multus B300 lathe (Fig. 2).

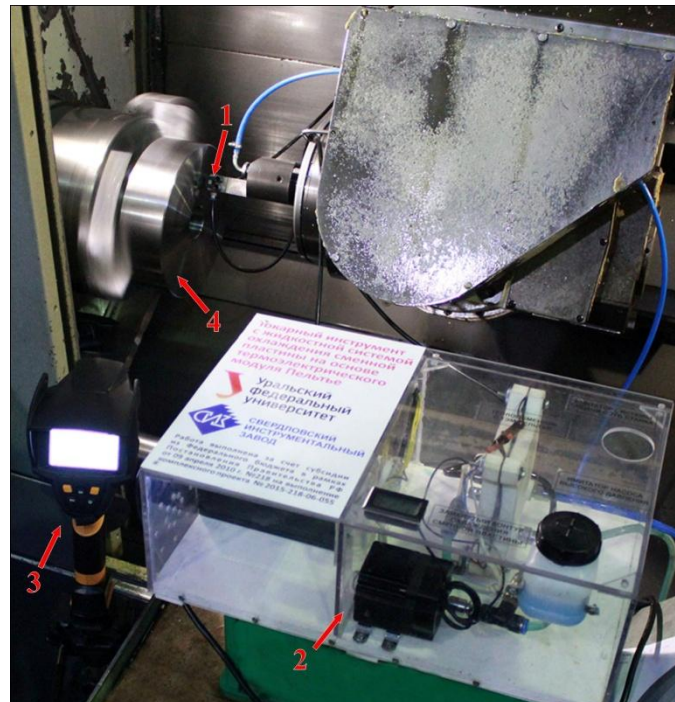


Figure 2. Turning tool with a closed loop system for cooling a replaceable cutting insert on an Okuma Multus B300 lathe: 1 – tool holder with the RCT; 2 – cooling system; 3 – thermovision camera; 4 – workpiece

Preliminary turning was performed with a Sandvik WNMG 080408-SM hard alloy cutting plate at a cutting speed of 80 m/min and a feed of 0.6 mm/rev.

Hard finishing turning of circular areas on the face was done with a SECO RNMM190400S-10020 round plate manufactured from CBN500 cubic boron nitride, its diameter being 19 mm. The cutting depth was set at $t=0.15$ mm, the feed was $f=0.15$ mm/rev. The cutting speed was set at 100, 200, 250 and 300 m/min separately for each path.

In the process of machining the temperature on the surface of the replaceable turning plate was measured with a Testo 875 thermovision camera. The roughness of the machined circular areas was measured by means of the contact method on a Calibr 170623 profilometer. The arithmetic mean value resulting from ten measurements of roughness was assumed to be the final result

3. Results and Discussion

Equally, when turning with and without heat removal, the dependence of the temperature of the RTP on the cutting speed turns out to be identical (Fig. 3). When the speed is raised from 100 to 250 m/min, the temperature grows linearly. Alternatively, increasing the speed from 250 to 300 m/min results a significant decline of the temperature of the RTP. In the case of machining without heat removal the maximum and the minimum temperature values of the RTP were 263 °C and 69 °C respectively. It was discovered that application of the cooling system leads to lowering maximum and minimum temperatures by 12% to 235 °C and by 32 % to 47 °C respectively. The significant temperature drop at 300 m/min may be attributed to lower friction in this speed range.

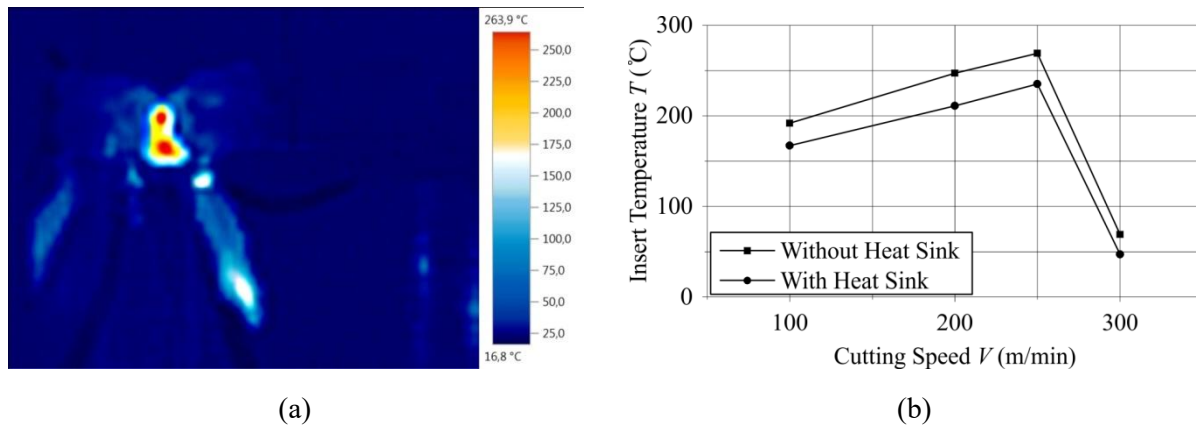


Figure 3. Thermograph of the cutting zone when machining without heat removal at 300 m/min (a) and dependence of the RTP temperature on the cutting speed (b)

Dependences of changes in the surface roughness as after turning exhibit an excellent correlation with the RTP temperature. Cooling the RTP is beneficial for increasing the surface smoothness; it is specifically evident for turning at 300 m/min. The roughness R_a goes down by 22% from 0.23 μm to 0.18 μm and the roughness R_z – by 26% from 1.43 μm to 1.06 μm .

Usage of the cooling system also contributes to reducing the wear of the RTP. At the optimal speed of 300 m/min the width of the wear flat in the tool tip decreases by 17% from 2.3 mm to 1.9 mm (Fig. 4).

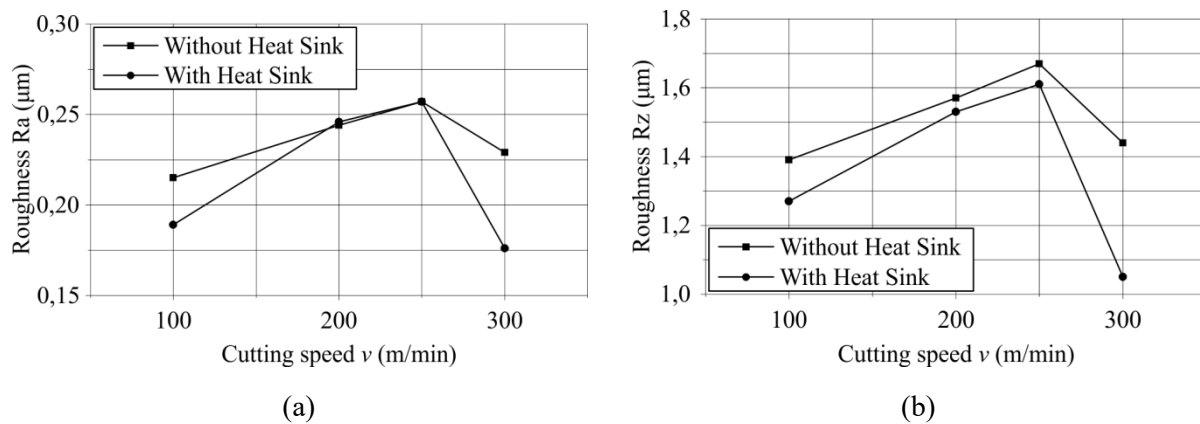


Figure 4. Dependence of roughness R_a (a) and R_z (b) on cutting speed

4. Conclusions

The research has proven that application of the closed loop cooling system results in both better smoothness of machined surfaces and longer tool lives of RTP's. It has been determined that the most favorable conditions for dry turning of a X20Cr13 steel welded layer exist at a speed of 300 m/min.

Application of the cooling system at the optimal speed leads to lowering the roughness R_a by 22% from 0.23 to 0.18 μm and the roughness R_z by 26% from 1.43 to 1.06 μm in comparison to machining with no heat removal. The width of the wear flat in the tool tip of the RTP goes down by 17%. Therefore, application of a closed loop cooling system is an efficient way for improving the quality of machining and the tool life of RTP's.

Acknowledgements

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